D3.5 Positive-normative configurations

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Executive Summary

AGRICORE is a research project funded by the European Commission under the RUR-04-2018 call, part of the H2020 programme, which proposes an innovative way to apply agent-based modelling to improve the capacity of policymakers to evaluate the impact of agricultural-related measurements under and outside the framework of the Common Agricultural Policy (CAP).

This deliverable reviews the approaches proposed for the AGRICORE tool from their initial meaning to their final implementation. These two approaches are positive and normative, both of which have been used previously in similar tools based on mathematical programming.

On the one hand, the positive approach is inherent to the purpose of the tool. This approach seeks to calibrate the mathematical model to achieve replicability of the agents' behaviour as close as possible to reality. To this end, data collection (WP1) and the generation of a synthetic population representative of the target population (WP2) are fundamental.

On the other hand, the normative approach was initially proposed as the functionality that the tool would have to optimise the parameters of agricultural policies in order to meet certain objectives. However, this approach is not entirely practical for policymakers and is rather limited by the computational cost of the required simulations. For this reason, an alternative approach with a close link to the positive approach was chosen.

Finally, since the positive approach coincides with the initial approach and the normative approach does not, other normative alternatives are proposed. These try to come closer to the initial approach of automating the derivation of parameters but taking into account the limitations mentioned above. Among the alternatives are the application of genetic algorithms and the development of a simplified agricultural policy impact model.

Abbreviations

Abbreviation	Full name
GDP	Gross Domestic Product
CAP	Common Agricultural Policy
MP	Mathematical programming
PMP	Positive mathematical programming
NMP	Normative mathematical programming
OECD	Organisation for Economic Co-operation and Development
FADN	Farm Data Accountancy Network
FAO	Food and Agriculture Organization
FSS	Farm Structure Survey
DWH	Data Warehouse
SPG	Synthetic population generation
DEM	Data Extraction Module
DFM	Data Fusion Module
ABM	Agent-based model
BEFM	Bio-Economic Farm Model
BN	Bayesian network

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1 Introduction

The AGRICORE project proposes a novel tool for improving the current capacity to model the impact of policies dealing with agriculture by leveraging the latest progress in agent-based modelling (ABM) approaches. Each agricultural holding (AH) is represented by an agent, i.e. an autonomous decision-making entity which individually assesses its own environment and makes decisions based on its current situation and expectations. This modelling approach will make it possible to simulate the interactions between each farm, its neighbouring farms, and its context (environmental surroundings, level of rural integration, services provided by the ecosystem, permitted uses of the land, etc.), both in terms of the availability of resources and services and the impact on the aforementioned components of the environment. Additionally, these farms will be able to interact with external modules, such as the land market module that enables land exchange. This simulation could be at different geographical scales, from regional (NUTS2) to European (NUTS0), and under the framework of one or more agricultural policies defined by the policy environment module.

The main potential beneficiary of the AGRICORE tool is the European Commission, which therefore funds the H2020 call RUR-04-2018 under which the project was awarded, and specifically, the Directorate-General for Agriculture (DG-AGRI), which is responsible for designing, implementing and evaluating the Common Agricultural Policy (CAP). Since European public policies in general, and especially the CAP, are living elements in a constant process of updating and improvement, the above-mentioned evaluation phases of certain policies may overlap with the design phases of future ones. This means that one of the requirements of AGRICORE is that the tool can be used both for ex-post policy impact assessment (usually with a good amount of data available on farm programme adherence levels and observed farm effects), and for ex-ante policy impact prediction (where obviously programme adherence levels and effects can only be simulated, usually on the basis of historical behaviour observed in the past). In either case, the model should calibrate well to those real situations that are known. In the case of ex-post analyses, the model can be calibrated to reproduce the baseline situation (at the time of entry into force of the policy programme under study) and the final situation (at the time of the end of the programme's life), assuming that both moments are prior to the impact analysis, and therefore that the necessary data are reliably known. In the case of ex-ante analyses, the model can be calibrated only to the baseline situation, or at least to the most recent known situation of the agents. Thereafter, the evolution of the system of agents is based on the assumption that the agents behave according to a set of rules drawn from data from their response to previous policy programmes and/or ad-hoc participatory research work carried out as part of the preparation of a given use case.

That is, in some cases, the research question to be answered by simulating the model is: why did agents make the decisions we have observed them making?; in other cases, the question is: what are the decisions agents should make to maximise the achievement of certain objectives? Approaches that answer the first question are called positive; those that answer the second question are called normative [1]. As will be seen in later sections of this deliverable, in the economic literature in general and in the specific literature on agricultural policy impact analysis, the concepts of positive and normative approaches, positive and normative models and positive and normative programming are sometimes used interchangeably, perhaps because until relatively recently each of the approaches/models was associated with one type of mathematical formulation structure. This has changed, however, thanks to the development of new calibration techniques for optimisation models [2], enabling positively calibrated models to be also used for normative applications, raising so-called positive-normative models [3].

On the other hand, it would also be wrong to associate positive approaches only with ex-post analysis, and normative approaches only with ex-ante analysis. An ex-post analysis can also be normative if the question to be answered is not why did the agents do what they did in certain circumstances, but what would have been their optimal behaviour in the presence of those circumstances. Similarly, an ex-ante analysis can be positive if it is assumed that the future behaviour of agents is known a priori (i.e., given that the state of the system of agents at t+k is known, what would be the motives that would lead agents to make the decisions leading to that state)?

The AGRICORE suite can be considered a positive-normative model, and this deliverable presents how both approaches have been developed. On the one hand, in the mathematical programming framework, the positive approach has been mainly employed to calibrate the models. Its objective is to replicate realistically and accurately as possible the known evolution of the population of agents under given policies. This is possible thanks to a large amount of collected data from different data sources (FADN, EUROSTAT, collaboration with stakeholders, etc.), which allows the generation of a representative synthetic population (see deliverables D2.3 and D2.4) and its subsequent calibration (D3.2). On the other hand, in the Grant Agreement, the normative approach was described as an AGRICORE automatic optimisation functionality to obtain the most suitable policy parameters to attain the policymakers' objectives.

Nevertheless, it is important to introduce here the possible confusion that may arise when speaking of normative configuration in terms of who is the subject of the normative action. As mentioned above, this configuration is aimed at determining what are the optimal actions to be followed by the agents, i.e. what is the optimal allocation of resources to achieve their objectives. In the literature on policy impact assessment, the subject of decisions is always the farmers. However, the resources (and their optimal allocation) are not the same if the subject of the analysis is the farmer as if the subject of the analysis is the policymaker. Both are normative approaches, but each one tries to answer a different research question:

- Research question for farmers: What should farmers do to maximise their objectives (e.g. profit maximisation), assuming they behave following certain rules and are constrained by a set of resource limitations and policy-imposed constraints?
- Research question for policymakers: What is the best set of policies to be implemented in order to reach some established objectives (e.g. improve environmental, societal or economic KPIs), assuming that farmers behave following certain rules and that the public administration is constrained by certain budgetary or socio-cultural limitations?

The remaining of this deliverable is devoted to explaining why we believe our model in its current approach can already answer the first question, using a positive-normative approach (seen from the side of farmers), while we propose two alternatives for trying to answer the second one, which to the best of our knowledge has not yet been resolved.

The following section explains the fundamentals of positive and normative approaches to have a global idea of their use and advantages. In the third section, the application of these approaches in the policymaking process, especially in agriculture, is described, together with the adapted aspects of the original ones. Finally, section 4 outlines the role and interaction between positive and normative configurations of the tool. Moreover, some alternative approaches are proposed to achieve a closer implementation of the initial normative proposition.

2 Positive vs Normative: conceptual differences

The positive and the normative concepts have their origins in philosophy and have subsequently been applied to numerous fields. These concepts have probably reached a greater dimension in the field of economics, defining two branches. It is from economics that the concepts of positive and normative were extrapolated to policy design. However, as [4] points out, there has not always been a clear distinction between the two terms and, to this day, controversy continues to exist in this regard. Economists' use of the positive-normative distinction has its origins in 19th-century classical political economy. The most important precedent in this respect was set by Mill [5] and Keynes [6] with their work, known as the Mill-Keynes tradition. Their positive vs. normative distinction intended to isolate the scientific part of economics from ethics and other social sciences, exemplified by the division between science and art. This positive vs. normative distinction has evolved over time to the more empirical character of economics today, as explained in [4]. However, since it is not the purpose of this deliverable and is beyond the scope of the project, their most current, simple and extended definitions are presented based on [7].

On the one hand, positive economics can be defined as the scientific branch of economics, whose objective is to analyse the economic phenomena from an objective view and aims to answer the question 'what is'. To this end, it is based on economic theories which have been empirically verified, so it requires measurable indicators that allow the detection of cause-effect relationships. On the other hand, normative economics bases its statements on value judgements, analysing economic phenomena subjectively to answer the question 'what ought to be'. In summary, positive economics conducts a descriptive analysis, while normative economics conducts a prescriptive analysis.

Although different, the two are complementary and necessary for the creation and implementation of effective economic measures. In fact, Mill argued the following in [5]: "the mere political economist, he who has studied no science but Political Economy, if he attempts to apply his science to practice, will fail". For this reason, both should ideally be applied holistically to make the most of their characteristics. Thus, a measure based on both theoretically and empirically proven facts (positive economics) has less room for error. Moreover, if such a measure is articulated considering the economic agents (concerns, behaviours, etc.) to which it will be applied (normative economics), it is likely to have a higher success rate.

Finally, daily life examples of positive and normative statements can be found in economics. For example, "a country's economy goes into recession when its GDP falls for two consecutive quarters" is a positive statement, as it is based on verified facts. In the same context, economic policymakers make their proposals to reverse the situation. According to their ideology, it is common to find these proposals "to raise taxes to collect more money so that the state can guarantee public services to the population" and "to lower taxes so that families have that money and dynamise the economy". These statements are clearly normative as they are based on a value judgement and have no theoretical basis.

3 Positive and normative configurations of Bio-Economic Farm Models for policy analysis

Bio-Economic Farm Models (BEFMs), such as AGRICORE, are a specific category of agricultural systems models that link the optimisation of farmers' resource management decisions to quantitative evaluations of inputs and outputs (including externalities) of alternative production possibilities [8]. Compared with other types of models that have been used for policy assessment, they provide some advantages related to the level of detail achieved in the representation of agricultural systems, namely: the possibility to incorporate large numbers of production options and technologies, the ability to explicitly account for interactions between crops and between crop and livestock activities, and the enabling of sensitivity analyses to assess the impact of uncertain parameters. Applications of BEFMs can be subdivided into three broad classes based on their purpose [9]:

1. Exploring the suitability of alternative farm configurations and technological innovations (i.e. assessing whether a technology will be viable financially and/or will have other positive side-effects).
2. Predicting or forecasting the effects of changing policies on agriculture (i.e. informing policymakers or groups of stakeholders about the plausible outputs of the implementation of a different set of policy-related instruments: subsidies, premiums, tax reductions, etc.).
3. Efforts to highlight methodological aspects of BEFMs and their improvements (i.e. publications usually addressed to other researchers to convince them of the new benefits of this type of model).

In the current century, two major literature reviews of BEFMs and their applications have been conducted within a decade of each other (Janssen and van Ittersum [9] in 2007 and Reidsma et al. [10]in 2018). The aim of the review by Janssen and Van Ittersum was to critically analyse the models existing at the time and the applications given to them (42 models applied in 48 studies). Based on their strengths and drawbacks, they outlined a research agenda to guide methodological efforts to enable the use of BEFMs in ex-ante evaluations of technological innovations and policies for farmers, policymakers and other stakeholders. The first contribution of this work was to consolidate the term (BEFM) used to describe this type of models, which has been used in publications for the next decade. Another contribution is the proposed classification of BEFMs:

- According to the conceptual principle on which they are based, they can be mechanistic or empirical.
    - An **empirical BEFM** uses historical series of data to extract correlations between the state of farms and their environment and the actions taken by their managers. These relationships are unknown a priori and are sought in an agnostic way (not guided by pre-conceived hypotheses). Based on the relationships obtained from past data, it can be extrapolated how farms will behave in the near future under similar stimuli and constraints.
    - A **mechanistic BEFM** is one that is constructed on the basis of a (theoretical-perceptual) explanation that the researcher previously has about the processes that actually occur on the farms. The main problem with these models is that their results can diverge greatly from the behaviour actually observed. Furthermore, they allow modelling behaviour in the longer term than empirical models and for a wider range of technical alternatives or political or environmental constraints, provided that the expected response has been modelled beforehand through participatory analysis.
- According to the approach, they can be normative or positive.

- **Positive approaches** describe the actual farm responses and try to understand the reasons behind them so as to generate a mathematical model that calibrates exactly to that known behaviour, hoping the model is also capable of predicting future responses.
- **Normative approaches** aim not so much to explain observed farm behaviour but to find the set of optimal resource allocation alternatives to maximise the assumed objectives of farmers. Therefore, a model used with a normative approach sets a 'norm' that defines what actions farm managers should take to optimise their results. Logically, there will be as many different norms as there are different models, and furthermore, none of these norms may ultimately coincide with the actual observed results. In this type of approach, differences between modelled and actual observed outcomes (usually lower than expected levels of adoption of new techniques or adherence to new policies) are attributed to a variety of reasons: imperfect information, risk aversion, bounded rationality, etc.

Regarding this latter classification, the application of positive and normative approaches in policymaking is a common practice, and it is also extended to agricultural policymaking, as shown in the previous section. These come to relieve the difficulty of articulating effective agricultural policy programmes, which, according to [11], are three. First, many of the non-commodities are not measurable, and commodity-related indicators have to be measured. For example, landscape quality can be measured by the number of animals and plants indigenous to the region. Second, these non-commodity products must be linked to social demand. Finally, the design of the policy must take into account the agricultural situation in the region where the policy will be implemented and the possible response of farmers.

Normative approaches to mathematical modelling are part of normative mathematical programming (NMP), which addresses the modelling problem from a prescriptive point of view. As was explained above, these approaches need to establish some norms and objectives from which to optimise the decisions of the process to be modelled. These norms and objectives are included as objective function parameters and constraints, avoiding the need for historical data to calibrate the model. All in all, it is a way to introduce prior knowledge in modelling but without considering the expected behaviour of the population of interest in response to the optimised parameters resulting from the model. For this reason, jumpy behaviour could be observed, which is problematic in high-geographical-resolution models, but this behaviour is less common thanks to the inclusion of non-linear objective functions and current computer capabilities [3].

In [12], the uses of NMP are enumerated as follows: i) prescription of solutions; ii) prediction of consequences; iii) demonstration of sensitivity; and iv) solution of systems of equations. In agriculture, considering the normative approach from the point of view of the policymaker described in Section 1, the first use would theoretically be the main function of NMP models, but it is the least common use in practice. This is due to the fact that policymakers give preference to their own judgement as they do not completely trust the outputs of NMP models. Therefore, the combination of predicting the effects that policies may cause on the population (second use) combined with the robustness of the model in assessing the results of slight variations in policies' parameters (third use) emerges as the most efficient approach for policy models to improve the policy design process.

On the other hand, the so-called "positive mathematical programming (PMP)" was formalised in [13]. PMP allows for the accurate reproduction of the observed farm production and the simulation of new market and policy scenarios while avoiding the drawbacks of MP. Recently the performance of such models has improved thanks to the plethora of available databases, especially in agriculture, with data on almost all types of exploitations at almost any geographical level. The term 'positive' is due to the assumption that the agents have a rational economic behaviour given all the observed and non-observed conditions. Thus, their behaviours reveal a production strategy based on farms' implicit cost of production. For this reason, PMP makes use of information provided by the dual variables of the calibration constraints to set a new model, which includes all the available economic information, and reproduces the farm behaviour under the optimization criteria. Based on it, PMP assesses the parameters of the non-linear object functions. To this end, the mathematical models must be properly defined, encompassing non-linear objective functions, linear constraints, endogenous variables, exogenous variables and parameters. In AGRICORE, the agent-based model is calibrated using a PMP approach based on FADN information at the NUTS 3 level and other data sources, hence the importance of data collection, processing and storage to reproduce the observed farms' behaviour.

Models based on PMP are of great interest to policymakers for their capacity to accurately reproduce an observed situation, which can be considered a "reference scenario", and to obtain a descriptive model that relates the inputs (policies in this case) and the outputs (e.g., the reaction of the target population and the made impact). For agricultural policymaking analysis, many models have used PMP as a supply partial equilibrium model. Some examples are listed below.

- **CAPRI** [14] is a regionalised agricultural sector model built for policy analyses addressed to crop and livestock production. It covers 280 NUTS2 regions from EU27, Norway, Turkey and Western Balkans. For its development, data sources from FADN, EUROSTAT, OECD and FAOSTAT were employed. The tool has two modules. On the one side, the supply module is in charge of maximising profit according to land supply, policy restrictions and feeding restrictions based on requirement functions. To do that, first, producers determine optimal variable input coefficients, and then the mix of crop and animal activities is optimised through cost-minimizing feed and fertilizer in the supply models. Additionally, a nonlinear cost function is constructed to take into account the impact of all variables that are not specifically addressed by limits or accounting costs, ensuring calibration of activity levels and feeding preferences in the base year and realistic responses of the system. On the other side, there is a market module with two sub-modules, one for agricultural products and another for determining the prices of young animals.
- **IFM-CAP** [15] is developed for the *ex-ante* assessment of the medium-term adaptation of individual farmers to policy and market changes with the aim of knowing how policy reform affects farm income, jobs, typologies of looser/gainer farms, scale, location and specialization of looser farms. The model can be applied to individual farms, solving a maximisation problem in terms of agro-management decisions subject to resource endowments (arable land, grassland and feed) and policy constraints (product prices and CAP subsidies). Among its outputs, the most remarkable ones are land allocation, livestock density, utilised agricultural area (UAA) of arable crop and grassland, land use change, agricultural production, CAP subsidies, intermediate input costs, variable costs, total costs, gross farm income, and net farm income. This model is calibrated following a positive mathematical programming approach and estimates model parameters from an observed base-year situation, considering the effect of not explicitly modelled factors. To this end, FADN data are used, as well as data from FSS, EUROSTAT and CAPRI databases.
- **SWISSLAND** [16] is an agent-based model based on FADN data and PMP. This tool is limited to the Swiss agricultural sector and allows for assessing how changes in agricultural policies, internal and external market forces, and the varied site characteristics unique to the alpine region will affect income trends, structural change, and land management. The model simulates the supply-and-demand market in Swiss agriculture, where each agent is an individual farm. On the supply side, the behaviour of producer, consumer and trade are modelled, and the product quantities and some structural and income figures are calculated. In this case, it is assumed that the farm managers try to maximise their expected household income, which determines the decisions made. On the demand side, food consumption, feed and processing demand are estimated with behavioural demand functions. Furthermore, the

market prices and supply-and-demand quantities are calculated considering endogenous and exogenous factors.

The AGRICORE model, as SWISSLAND, is also an agent-based model based on FADN and PMP but differently from SWISSLAND, AGRICORE ABM considers not only information from the FADN data, which are enriched through participatory research actions; furthermore, it foresees the possibility to exchange technology among farm holdings. Although complex, the agent-based approach is a good technique to measure the uptake and impact of new market conditions and new agricultural policies, as there are clear differences in the farmer's attitudes in different farm types and locations. Therefore, policymakers have an interest in designing agricultural policies that are tailored to the needs of each region or agricultural sector. This is the aim of tools such as AGRICORE.

4 Positive and normative configuration in the AGRICORE suite

Having explained the differences that exist to date at the theoretical-conceptual level to distinguish between positive and normative applications of BEFMs, the configurational nature of AGRICORE can be described. The first thing to note is that the AGRICORE model is a dynamic recursive model. This means that the planning of all agents (remember that each agent represents an Agricultural Holding) is (re)optimised at each simulation step, taking into account in each iteration the expected evolution of the farm as a result not only of the optimal actions in the present instant but of the whole sequence of future actions until the end of the simulation period (sliding prediction horizon). This implies that the optimisation process contemplates which structural and economic state the farm would be led to by the alternative actions that the farm manager can take, both in the immediate campaign and in the remaining ones until the end of the simulated period. One or several sub-models are used to explicitly account for the dynamic interactions between years/campaigns using as initial states for each future campaign the final states of the immediately preceding campaign, as computed by the model(s).

In order to incorporate this predictive capacity into the optimisation, two distinct but interrelated sub-models are used (deliverable D3.2). The first sub-model is a structural model that computes the expected long-term (LT) evolution of the financial state of the farm as a trading company (i.e. profitability, solvency and liquidity). This model is used by a State Space Economic Model Predictive Controller (SS-EMPC) that artificially represents the intelligence/rationale of the farm manager in making the structural decisions of the farm, namely: enlargement-reduction of the economic size of the company, acquisition-disposal of fixed assets (land and/or machinery), and acquisition-revocation of credit liabilities. This sub-model optimises by assuming that the managers of all farms (i.e. all simulated agents) seek to maximise their profitability but try to ensure that the solvency and liquidity ratios of their farm businesses do not deviate from pre-defined target values. Evidently, this is a completely normative assumption taken by the AGRICORE modellers.

The second sub-model is an economic model that computes the short-term (ST) operation of the farm as an agricultural production unit (i.e. the optimal allocation of fixed and current assets to the available alternative agricultural activities). This is a PMP model that assumes that all farm managers seek to maximise their annual profits and is calibrated using real historical data corresponding to samples of farms located in the same geographical area as the one assigned to each agent. It is very important to mention here that the initial synthetic population of agents is constructed using synthetic reconstruction techniques (SR) based on the use of Bayesian networks (see deliverables D2.3 and D2.4), which ensures that the distribution of values for each agent attribute in the synthetic population reproduces the probability density function of that attribute in the real population. That is, the AGRICORE model is inherently positive in two ways: i) the fact that the initial population of agents is constructed by synthetic reconstruction from a sample of the real population under study, and ii) the fact that the short-term PMP agroeconomic model is calibrated using microeconomic data from another sample of farms from the same real population under study. The former allows the population of farms at t=0 of the simulation to reproduce the levels observed at the baseline year at the global level (for the entire real population) of production of each product, land devoted to each activity, and average economic size of the farms; the latter guarantees that these levels will not change abruptly after the initial iteration of the optimisation-simulation procedure (avoiding the jumpy behaviour typical of pure normative models).

A circumstance that has not been mentioned so far is the fact that the positive calibration of the AGRICORE model implicitly includes the effect that all instruments associated with public agricultural policies, past or ongoing, have on each population of farms. In other words, by using agro-economic data sources, the PMP model takes into account the implicit costs that participating (or not) in the agri-environmental programmes and commitments has had for farmers up to the time of data collection. Irrespective of this, the mathematical formulation of the objective function of the optimisation model allows for explicitly incorporating, by means of an ad-hoc term, certain specific policies.

The PMP calibration is possible thanks to the availability of farm-holding data at the regional, national and European levels. In fact, WP1 is entirely dedicated to the search and characterisation of data sources. Although the main data source is the FADN, many other datasets have been obtained from public institutions (FAO, FSS, EUROSTAT etc.), through collaboration with stakeholders (agricultural cooperatives, public institutions, databases generated by other previous projects, etc.) and through participatory research. For the management, processing and storage of such a huge amount of data, several integrated auxiliary tools are necessary, such as the Data Warehouse (DWH), the ARDIT tool, the Data Extraction Module (DEM) and the Data Fusion Module (DFM). It can therefore be said that **the AGRICORE model always shows a positive approach** to the policy measures and the economic-structural characteristics of the population that is the subject of analysis.

Once initialised and calibrated, the model allows for simulating the effect of certain measures and instruments associated with the CAP. These measures can be a) identical to the existing ones (that already conditioned the data used for the calibration), b) similar to the existing ones but varying the value of some of their defining parameter(s) (see deliverable D5.7 for a proposal of a standardised description of agricultural public policies), or c) measures and instruments of novel structure not comparable to any of the existing ones. The effect of these instruments is assessed by analysing, on an aggregate (through global averages) and/or individualised basis, the evolution of the agents' states during the different simulation steps, including their final state.

The analyses thus performed have an inherently normative nature, even if the model is not modified by terms or coefficients resulting from specifically dedicated studies. One can think of a model derived to predict the reaction of the real population to certain specific instruments (for example, through the results of an ad-hoc survey campaign dedicated to finding out the relationship between the monetary amount per hectare of a given agri-environmental scheme, and the probability that livestock farmers in a certain region of Poland would join the scheme). The normativeness of this configuration of AGRICORE arises from its use as a predictor of the consequences (#2 among the uses of NMP described in the previous section) associated with the level of adherence to the measure(s) under analysis, as determined by the simulation. In summary, the argument put forward in this section is that AGRICORE is a dynamic recursive model for the simulation of CAP measures and instruments, **whose approach is generally positive-normative** when the subject of the optimisation is the individual farms (i.e. when the aim of the simulation is to see how agents will react - by adhering or not - to a policy setup, and how this reaction will eventually affect their structure and agronomic status in the future).

However, this project's proposal suggested, perhaps misusing the term, an alternative configuration mode for the AGRICORE tool, called the NORMATIVE configuration. The idea was to shift the point of view of the analysis from trying to answer the question "how will a policy with certain parameters affect farmers?" to trying to answer the question "what should be the optimal value of the parameters of a policy in order for it to maximise a certain effect that the policymaker has set as a target?". This change in point of view is not trivial because it also fundamentally changes who the subject of the optimisation is, but it is completely aligned with the use #1 of the NMP listed above (prescription of solutions).

In the first case, which we have previously called positive-normative configuration, the focus is on finding out the effect that the way in which managers plan (optimise) the operation of farms in the presence of certain policies has on the primary sector and on the environment. The subject that performs the optimisation is the human person who acts as the manager in each agent (in each of the simulated farms), who is presumed to have a set of rules of behaviour. But in the second case, for which we propose the term PRESCRIPTIVE configuration, what is sought to be answered is what the mix of public policies and regulatory instruments should be and the value of the parameters that define them in order to maximise the achievement of the global objectives of the policy, previously established by the Community legislator. The subject that carries out the optimal assignation of resources is, in this case, the policymaker, who is presumed to be guided by a series of pre-imposed objectives, but limited by a series of constraints (fundamentally budgetary but also related to its coercive capacity over the farms).

While the proposal included the implementation of this 'prescriptive configuration' that would "automatically choose the best parameters defining a policy scheme" based on an objective function related to the goodness of the key performance indicators associated with the evaluation of such a scheme, the reality is that such implementation has proved to be too ambitious a goal for the scope of the AGRICORE project. However, in the final section of this deliverable, two possible approaches are presented to at least begin to tackle the mathematical problem associated with this prescriptive approach.

5 Conclusions

In this deliverable, the positive and normative configurations of the AGRICORE suite are described. These are slightly different from the initial conception from the initial development phase of the tool. However, with the current configurations, it is believed that the tool will provide results that are in line with reality while enhancing its practical use in the design of agricultural policies.

On the one hand, the positive approach of the tool is inherent in its development, as PMP is used as the calibration method. This method guarantees a realistic behaviour of the synthetic population, which may entail that the extrapolation of results will be more straightforward. Furthermore, this has been made possible by the availability of data sources at regional, national and European levels in the agricultural sector. Hence, the special importance of WP1, which is in charge of data collection, processing and storage. On the other hand, the normative approach is not suited to the automatic generation of agricultural policies, as it might reduce their practical application by policymakers. Therefore, in the current approach, this automation loses some weight in favour of judgements based on the expert knowledge of agricultural policymakers. As a result, based on this knowledge, a set of agricultural policies can be defined and then, under each policy or combination of them, launch simulations to evaluate the evolution of the synthetic population and the impact caused.

Therefore, it can be concluded that the AGRICORE tool has been developed as a positive-normative approach to assist agricultural policymakers in designing policies. The added value of the tool is that it enables accurate ex-post policy impact assessment and ex-ante policy impact prediction based on historical data, which allows for the generation of representative synthetic populations and calibration of the ABM model. For the ex-post analysis, the model is calibrated to reproduce the baseline situation and the final one of the population of interest under the framework of an agricultural policy context. In the case of ex-ante analyses, the model can be calibrated only to the baseline situation and thereafter, the evolution of the system of agents is based on the assumption that the agents behave according to a set of rules drawn from data from their response to previous policy programmes and/or ad-hoc participatory research work carried out as part of the preparation of a given use case. In this case, the agricultural policy context is changeable for a suitable policy design. For this reason, several alternative agricultural policies will be defined under the suggestions and convictions of stakeholders (policymakers, agricultural associations, academic institutions, etc.) collected through participatory research activities. Indeed, thanks to the responses of farmers in the survey campaign, certain gaps in current policies and the needs of farmers and their farms can be identified and reflected in the designed policies. Thus, the target population is actively involved in this process, resulting in more attractive policies with a higher uptake. With the set of alternative policies, the constraints of the parameters of the agricultural policies are indirectly set. These policies will be simulated individually or in combination, and the results obtained in terms of synthetic population evolution and impact assessment will be observed. Therefore, it follows that an important strength of this policy approach lies in the PMP calibration, as it ensures that the hypothetical results obtained are realistic, hence the complementary behaviour of both.

5.1 Future work

Given the deviation with respect to the initial normative configuration, this section proposes alternative approaches that are closer to the automation of the policymaking process. Nevertheless, these approaches maintain the main role of the knowledge of the agricultural policymakers, avoiding the loss of applicability in practice. These developments entail a more explicit definition of the policy parameters constraints by the policymakers and a more broad exploration of these parameters by mathematical optimisation methods, such as metaheuristics algorithms and genetic algorithms. However, the high computational cost and simulation time must be considered. To this end, the constraints can also include fixed parameters and forbidden combinations, such as higher subsidy amounts and a high minimum plot size, which would rocket the budget of the policy. Additionally, continuous parameters could be discretised in order to limit their value spaces.

Considering the aforementioned constraints, a possible metaheuristics algorithm is Taboo Search, which has been used in previous optimisation problems in agriculture, such as [17] and [18]. In this algorithm, a feasible solution is started, and a local search is done in the neighbourhood of that solution, which is determined by a neighbour generation function and one or more tabu lists [19]. Thus, the following elements will need to be defined:

- Neighbour generation function. Neighbours could be generated from the baseline solution, which in this case is an agricultural policy, by changing one or more of the parameters that define it.
- Taboo lists. In this algorithm, a typical taboo list is filled with the solutions that have been evaluated previously in order to avoid internal loops in the search. Moreover, each of the constraints defined to simplify the search could be a taboo list.
- Size of the taboo list(s). The taboo lists created from the constraints have a fixed size, but the other does not. Depending on the memory size, the search can be intensified, re-evaluating previously explored solutions, and diversified with the exploration of new neighbourhoods.

With these elements, the implementation of the Taboo Search can be customised according to the computational cost and the solution space. In the following, the steps of a possible algorithm implementation are listed, which will end when no better solutions are found, or a maximum number of iterations have been executed.

1. A baseline solution is proposed, which could be the current agricultural policy to be improved.
2. A neighbourhood of policies is determined by the neighbour generation function. For example, the function could return all those policies that arise from changing a single parameter to the starting solution according to its value space.
3. The generated neighbours are checked according to the taboo lists, and those that entail a taboo are removed.
4. All the neighbours are evaluated with a simulation, and their KPIs are obtained.
5. The explored neighbourhood are included in the taboo list. If the list is fully filled, the oldest explored solutions are removed until the new entry explored solutions could be saved.
6. If no neighbour improves the KPIs of the baseline solution, the neighbourhood is increased by changing one more parameter of the initial policy, going back to step 2. If this is not possible to increase the neighbour more, it is concluded that no better solutions can be found from the initial policy, and it is returned as the best policy.
7. If a better policy is found, this becomes the baseline solution and is saved as the best-found solution, going back to step 2.
8. If the maximum number of iterations is reached, the algorithm returns the best solution.

The other approach is based on genetic algorithms, which have been used in previous work related to agricultural policy design, such as [20] and [21]. These are suitable to solve complex problems in which even it is not possible to establish if an efficient solution exists, so optimality is not guaranteed, but it is less probable to stagnate in local optima by using a population of solutions. Moreover, they are easy to implement and parallelizable, allow for incorporating expert knowledge and usually improve the efficiency of search algorithms. These algorithms try to establish parallelism with biological evolution, where there is a population of individuals (solutions) defined by their genotypes composed of genes (features) and they evolute and survive according to the adaptation to the environment [19]. On the one hand, evolution generates new individuals based on two genetic operators:

- **Mutation**. Random, usually slight, modification of the genotype of the individual. It is not mandatory in genetic algorithms, but it is commonly used because it allows for intensifying the search for solutions in the space of the current population.
- **Cross-over**. Combination of the gene sequences of two or more individuals to generate new ones. This can be made by randomly cutting the gene sequences of the parents by one point (1-point crossover), *n* points (n-points crossover) or selecting the parent of each gene (uniform crossover).

On the other hand, the adaptation of the individuals to the environment is determined by a fitness function, which is related to the objective of the problem. According to it, a survival probability is assigned to each individual, influencing the probability of combining (the most adapted individuals will prevail more in the population and be the parents of new individuals). In addition to basing survival in individuals on a fitness function, there are other methods, such as age (descendants replace parents) and elitism (the best individuals always survive).

In the case of optimising the design of agricultural policies, the initial population could be a set of existing and tentative policies, which are defined by some features. Furthermore, expert knowledge can be integrated into the algorithm with the aforementioned constraints. A complete diagram of a simple solution with this approach is shown in Figure 1. This is a simplified case where there are four policies (P1, P2, P3 and P4), each of them defined with four parameters (A, B, C and D). In the jargon of genetic algorithms, the individuals are the policies and the genes are the parameters. In this process, mutations and crossovers are conditioned by the constraints. However, another common implementation is to only apply this knowledge in the mutation step, carrying out a selective mutation that guarantees that the individuals generated in the previous step meet the constraints.

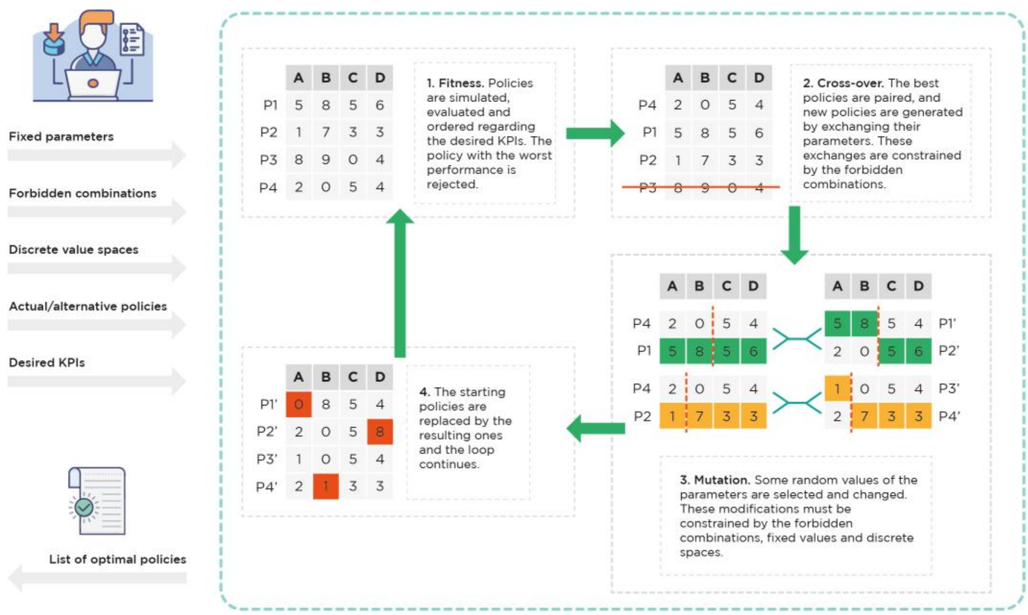

Figure 1 Normative mathematical approach with genetic algorithm.

Since the feasibility of the previous alternative cannot be ensured beforehand because it depends on the complexity of the use case, another approach is proposed. In this case, a deep analysis of the correlations between the policy parameters and the obtained results in terms of the evolution of the synthetic population and the impact caused will be required. The process would be similar to the generation of the synthetic population based on FADN data, and the objective would be to obtain a set of common correlations to build a simple model of the application of agricultural policies (see Figure Y). With this information, the mathematical optimisation of the previous alternative approach does not have to be so accurately constrained because the simulation would be simple, and more of them could be carried out. However, the main disadvantage is that much data are necessary to obtain a sufficiently reliable model.

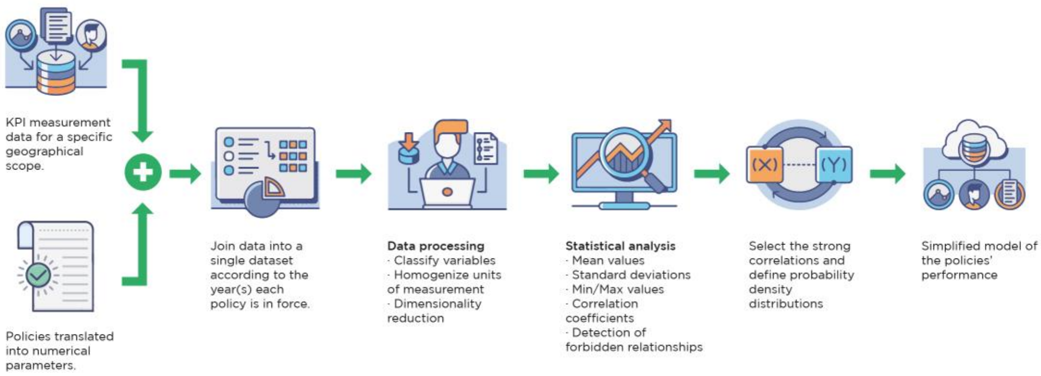

Figure 2 Process to obtain a simplified model of the impact of agricultural policies.

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For preparing this report, the following deliverables have been taken into consideration:

Deliverable Number	Deliverable Title	Lead beneficiary	Type	Dissemination Level	Due date
D2.2	Big data extraction module	AUTH	Other	Public	M36
D2.3	Big data fusion module	AUTH	Other	Public	M36
D3.1	Non-linear dynamic model of the farm agents	IDE	Report	Public	M31
D3.2	AI-based farmer's behavioural foundation	IDE	Report	Public	M31
D3.3	Model interaction capabilities for the ABM	IDE	Report	Public	M31
D5.1	State of the art review of agricultural policy assessment models, tools and indicators	UNIPR	Report	Public	M12
D6.2	External interface module	IDE	Other	Public	M31